

CLAIMS:

1. A fuel injection control apparatus for an internal combustion engine, wherein the internal combustion engine includes a cylinder, an intake passage, which is connected to the cylinder, a main fuel injection valve, and an auxiliary fuel injection valve, wherein the main fuel injection valve directly injects pressurized fuel, which is supplied from a high pressure pump, to the cylinder, and wherein the auxiliary fuel injection valve injects fuel to the intake passage, the apparatus comprising:

a controller for controlling the main fuel injection valve and the auxiliary fuel injection valve,

wherein the controller causes the auxiliary fuel injection valve to inject fuel during cranking of the internal combustion engine and determines whether the pressure of the pressurized fuel is greater than or equal to a predetermined value,

wherein the controller predicts whether the pressure of the pressurized fuel decreases below a permissible value, which is less than the predetermined value, due to injection of pressurized fuel by the main fuel injection valve during a period from a point of time after the pressure of the pressurized fuel becomes greater than or equal to the predetermined value till when fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder through the intake passage, and

wherein, when the pressure of the pressurized fuel is greater than or equal to the predetermined value, and it is predicted that the pressure of the pressurized fuel will not decrease below the permissible value during the period, the controller causes the main fuel injection valve to start injecting the pressurized fuel.

2. The fuel injection control apparatus according

to claim 1, wherein the controller predicts a decreasing amount of the pressurized fuel during the period based on the number of times the main fuel injection valve injects fuel during the period.

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3. The fuel injection control apparatus according to claim 2, wherein the high pressure pump repeatedly executes a pumping process of pressurized fuel when the internal combustion engine is running, wherein the  
10 controller obtains the number of times the pumping process is executed during the period, and wherein the controller obtains the number of times of injection during the period based on the obtained number of times of the pumping process.

15 4. The fuel injection control apparatus according to claim 1, wherein, from when the injection of the main fuel injection valve is started till when the fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder, the controller causes the main fuel  
20 injection valve to inject an amount of fuel required for cranking the internal combustion engine.

5. The fuel injection control apparatus according to claim 1, wherein, after fuel injected from the auxiliary  
25 fuel injection valve has reached the interior of the cylinder, the controller causes the main fuel injection valve to inject an amount of fuel less than a required amount for cranking the internal combustion engine.

30 6. The fuel injection control apparatus according to claim 1, wherein the predetermined value is determined in accordance with the temperature of the internal combustion engine.

35 7. A fuel injection control apparatus for an

internal combustion engine, wherein the internal combustion engine includes a cylinder, an intake passage, which is connected to the cylinder, a main fuel injection valve, and an auxiliary fuel injection valve, wherein the main fuel injection valve directly injects pressurized fuel, which is supplied from a high pressure pump, to the cylinder, and wherein the auxiliary fuel injection valve injects fuel to the intake passage, the apparatus comprising:

means for causing the auxiliary fuel injection valve to inject fuel during cranking of the internal combustion engine;

means for determining whether the pressure of the pressurized fuel is greater than or equal to a predetermined value during cranking of the internal combustion engine;

means for predicting whether the pressure of the pressurized fuel decreases below a permissible value, which is less than the predetermined value, due to injection of pressurized fuel by the main fuel injection valve during a period from a point of time after the pressure of the pressurized fuel becomes greater than or equal to the predetermined value till when fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder through the intake passage; and

means for causing the main fuel injection valve to start injecting the pressurized fuel when the pressure of the pressurized fuel is greater than or equal to the predetermined value and it is predicted that the pressure of the pressurized fuel will not decrease below the permissible value during the period.

8. A controlling method of a fuel injection control apparatus of an internal combustion engine, wherein the internal combustion engine includes a cylinder, an intake passage, which is connected to the cylinder, a main fuel injection valve, and an auxiliary fuel injection valve,

wherein the main fuel injection valve directly injects pressurized fuel, which is supplied from a high pressure pump, to the cylinder, and wherein the auxiliary fuel injection valve injects fuel to the intake passage, the method comprising:

causing the auxiliary fuel injection valve to inject fuel during cranking of the internal combustion engine;

determining whether the pressure of the pressurized fuel is greater than or equal to a predetermined value;

predicting whether the pressure of the pressurized fuel decreases below a permissible value, which is less than the predetermined value, due to injection of pressurized fuel by the main fuel injection valve during a period from a point of time after the pressure of the pressurized fuel becomes greater than or equal to the predetermined value till when fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder through the intake passage; and

causing the main fuel injection valve to start injecting the pressurized fuel when the pressure of the pressurized fuel is greater than or equal to the predetermined value, and it is predicted that the pressure of the pressurized fuel will not decrease below the permissible value during the period.

9. The method according to claim 8, further comprising predicting a decreasing amount of the pressurized fuel during the period based on the number of times the main fuel injection valve injects fuel during the period.

10. The controlling method according to claim 8, wherein the high pressure pump repeatedly executes pumping process of the pressurized fuel when the the internal combustion engine is running, the controlling method further comprising:

obtaining the number of times the pumping process is executed during the period; and

obtaining the number of times of injection during the period based on the obtained number of times of the pumping process.

11. The controlling method according to claim 8, further comprising injecting an amount of fuel required for cranking the internal combustion engine from the main fuel injection valve from when the injection of the main fuel injection valve has started till when the fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder.

12. The controlling method according to claim 8, further comprising injecting an amount of fuel less than the required amount for cranking the internal combustion engine from the main fuel injection valve after the fuel injected from the auxiliary fuel injection valve reaches the interior of the cylinder.